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An experimental comparison of a mouse and arrow-jump keys for an interactive encyclopedia

JOHN EWING, SIMIN MEHRABANZAD, SCOTT SHECK, DAN OSTROFF AND BEN SHNEIDERMAN†

Department of Computer Science, University of Maryland, College Park, Maryland 20742, U.S.A.

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This paper reports on an experiment which was conducted to examine relative merits of using a mouse or arrow-jump keys to select text in an interactive encyclopedia. Timed path traversals were performed by subjects using each device, and were followed by subjective questions. Personality and background of the subjects were recorded to see if those attributes would affect device preference and performance. The arrow-jump keys were found to have the quickest traversal times for paths with either short or long target distances. The subjective responses indicated that the arrow-jump method was overwhelmingly preferred over the mouse method. Personality type was not found to play a critical role.

1. Introduction

This report describes a project that investigated the preference and performance of people using various selection techniques for an interactive encyclopedia. The selection devices studied are a mouse and four arrow-jump keys on a keyboard. These devices were examined for use in conjunction with TIES (The Interactive Encyclopedia System). TIES presents screens of information to the user, with a varying number of highlighted words on each screen. Users of this system may move the screen's cursor to one of the highlighted words and obtain detailed information regarding that word. Our project studied two ways to position the cursor, to identify which device is associated with higher performance times and with higher user satisfaction.

1.1. SCREEN FEATURES OF TIES

The screen used is that of an IBM PC with a monochrome display. The body of the text appears in the middle of the screen with half-inch margins on the sides and one-inch margins on the top and bottom (Fig. 1). The words which have an associated definition or related article are highlighted, i.e. displayed in brighter characters. The name of the current article on the screen appears on the top left-hand corner. The location of the current screen within a specific article is noted in the top right-hand corner of the screen. There are various keywords on the bottom of the screen, depending on the article. These keywords are highlighted and may be selected with the selection device. The keywords may include one that allows the user to return to the previous article (RETURN TO ⟨Previous Article⟩), one that advances to the next page (NEXT

† Author for correspondence.

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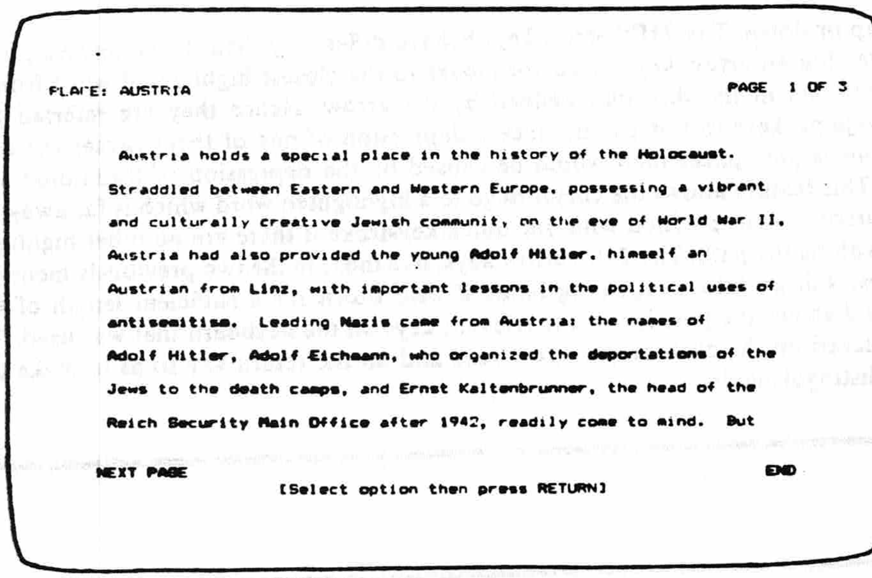

FIG. 1. A sample screen appearing in TIES. Words/phrases which would be in brighter characters are shown here in dark print.

PAGE), one that causes the display to go back to the previous page (BACK), and one that will take the user out of the system (END).

Some words have definitions as opposed to associated articles. These definitions are displayed in a box which takes up the lower half of the screen with RETURN TO (Previous Article) as a highlighted keyword.

For any screen, the cursor always starts out on the lowest leftmost highlighted word/phrase ("NEXT PAGE" in the case of the screen shown in Fig. 1).

1.2. EXPECTED USERS OF THE DEVICES

TIES has been designed for eventual use in a museum. The users of the system (and the selection device associated with it) are therefore likely to have a broad range of computer background and personality traits. Part of our experiment is to try to see whether personality traits or computer background has an effect on determining which device is preferable. If a dependence on either of these factors is found, then that result is relevant to the decision as to which device should be adopted for TIES, since that system should optimally be appealing to people of all backgrounds.

1.3. FEATURES OF THE SELECTION DEVICES

The arrow-jump keys consist of the four standard arrow keys found on most keyboards. In using the arrow-jump method, the user positions the cursor on the desired word and presses the return key in order to select an item in the encyclopedia. Previous studies by Card, English & Burr (1978) and Sweetak & Miller (1982) report results of timing tests for arrow keys in which pressing one of the horizontal keys moved the cursor one character along the line and pressing a vertical key moved the cursor one line up or down. The TIES arrow keys behave differently than theirs however, in that by pressing an arrow key the cursor moves to the closest highlighted word from the original one in the direction defined by the arrow. Hence they are referred to as arrow-jump keys in this paper, since a depression of one of them causes the cursor to jump larger spaces than would be caused by the depression of traditional arrow keys. This feature allows the cursor to go to a highlighted word which is far away from the current cursor position with one quick keystroke if there are no other highlighted words along the path. The TIES arrow keys, like those in the two previously mentioned studies, will go into a repeating mode if held down for a sufficient length of time. Figure 2 shows the position of the relevant keys on the keyboard that was used. Tape was placed on the each of the arrow keys and on the return key so as to make them very distinguishable.

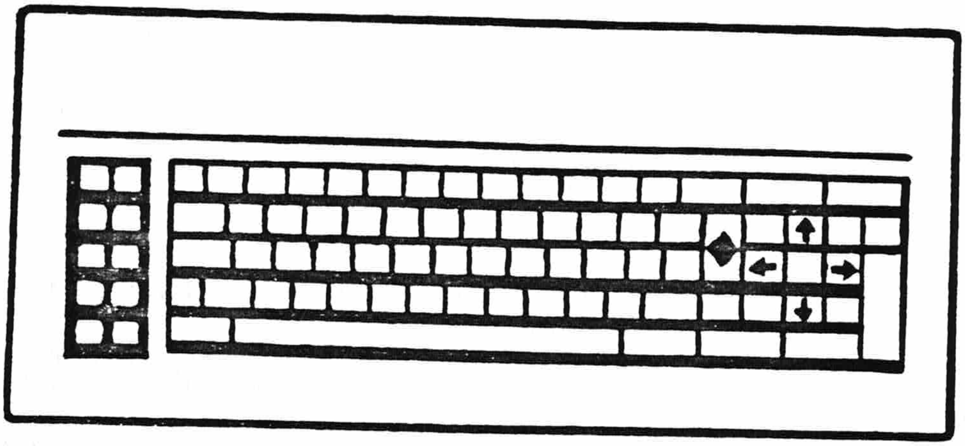

FIG. 2. Position of arrow keys and return key on the keyboard used. The return key is marked by a diamond.

The mouse used in this experiment is a small device which sat on a table at the side of the keyboard and is connected to the computer by a thin wire. The table surface was smooth and allowed the mouse to be moved within an approximately 4 square foot area. As the mouse is moved over the table by the user, a small sphere under the mouse rotates and details of its motion are transmitted to the computer, which moves the cursor in the direction of the mouse movement and at a speed proportional to the speed of the mouse. Movements of the mouse resulted in a consistently high quality of response throughout our experiments. After the cursor is positioned on an appropriate highlighted word, the user may press either one of two mouse buttons to select that word. Pressing one of the mouse buttons has no effect unless the cursor is positioned on a highlighted word. Most mice, as noted by Merkin (1983), have one to four buttons; and user tests as mentioned by Williams (1983) have found that one-button mice are sometimes preferable since naive users are not always sure which button to press on a multiple-button mouse.

1.4. FACTORS INVOLVED IN PERFORMANCE AND USER SATISFACTION

A number of previous experiments regarding performance with various selection devices are discussed throughout the literature, of which one of the most interesting and thorough ones is described by Card *et al.* (1978). They attempted to evaluate four devices with respect to how rapidly they can be used to select text on a CRT. The devices tested were: arrow keys, a mouse, a joystick, and a few special text keys. In their experiment, a single word or phrase constituted a target on the screen (the target's characters were in inverse video). The subject, after seeing the target, struck the space bar of the keyboard and then reached for the positioning device and directed the cursor to the target. After the cursor was positioned, the subject pressed a button associated with the selection device to select that target. The targets varied in size and in distance from the starting position. The experiments were primarily concerned with performance after long-term usage, hence each of the subjects used each positioning device until the positioning time for various target situations was no longer decreasing with practice. Accordingly, the subjects used each device for a few days while performing approximately 600 target selections per day. The number of participants was constrained by the length of time required of each participant and by financial reimbursements due to the participants. Therefore results are only presented for four subjects who each used all four devices. The subjects were all undergraduate students.

The first part of that study's results describe the improvement of performance with practice. Learning curves which give positioning time as a function of amount of practice were fit to the timing results of each device. Good fits were found based on a theoretical equation described by De Jong (1957) with empirically derived constants. Among other things, it was found that practice causes considerable improvement with the mouse and very little improvement with the arrow keys.

A comparison was made regarding the speed of using each device when the users were very familiar with those devices. The total time in selecting a target was defined as the sum of the homing time (defined as the time between when the subject's hand left the space bar and when the cursor began to move) and the positioning time, which was measured from when the cursor began to move until when the selection button was pressed. It was found that homing time increases slightly with the distance of the device from the keyboard. The mouse was found to have the shortest positioning and total times of all four devices and the arrow keys had the longest positioning and total times, even though that method had the shortest homing time.

Card *et al.* then presented results regarding a factor which is very critical to device comparisons: the distance to the target. Their results remarkably show that for very short target distances, the arrows are the quickest of all four devices and for distances over 1·5 cm the mouse is the quickest device (Fig. 3). The difference in speed between the mouse and arrows increases with distance. For distances over 15 cm the mouse is three times quicker than the arrows.

The effect of target size was also investigated. The positioning time for both mouse and arrows was found to decrease roughly with the log of target size.

The effect of the approach angle was studied as well. Cursor movements of the subjects were classified into vertical, horizontal, and diagonal groups. Analysis of variance shows the angle makes a significant difference (level not stated) for every device except for the mouse. Finally, the mouse was found to have the lowest overall error rate (5%) and the arrow keys had the highest (13%). The difference here was found to be significant at the 5% level.

Card *et al.* then attempted to provide a theoretical account for the results that were obtained. Their explanation is based on the so-called Fitt's law as described by Welford

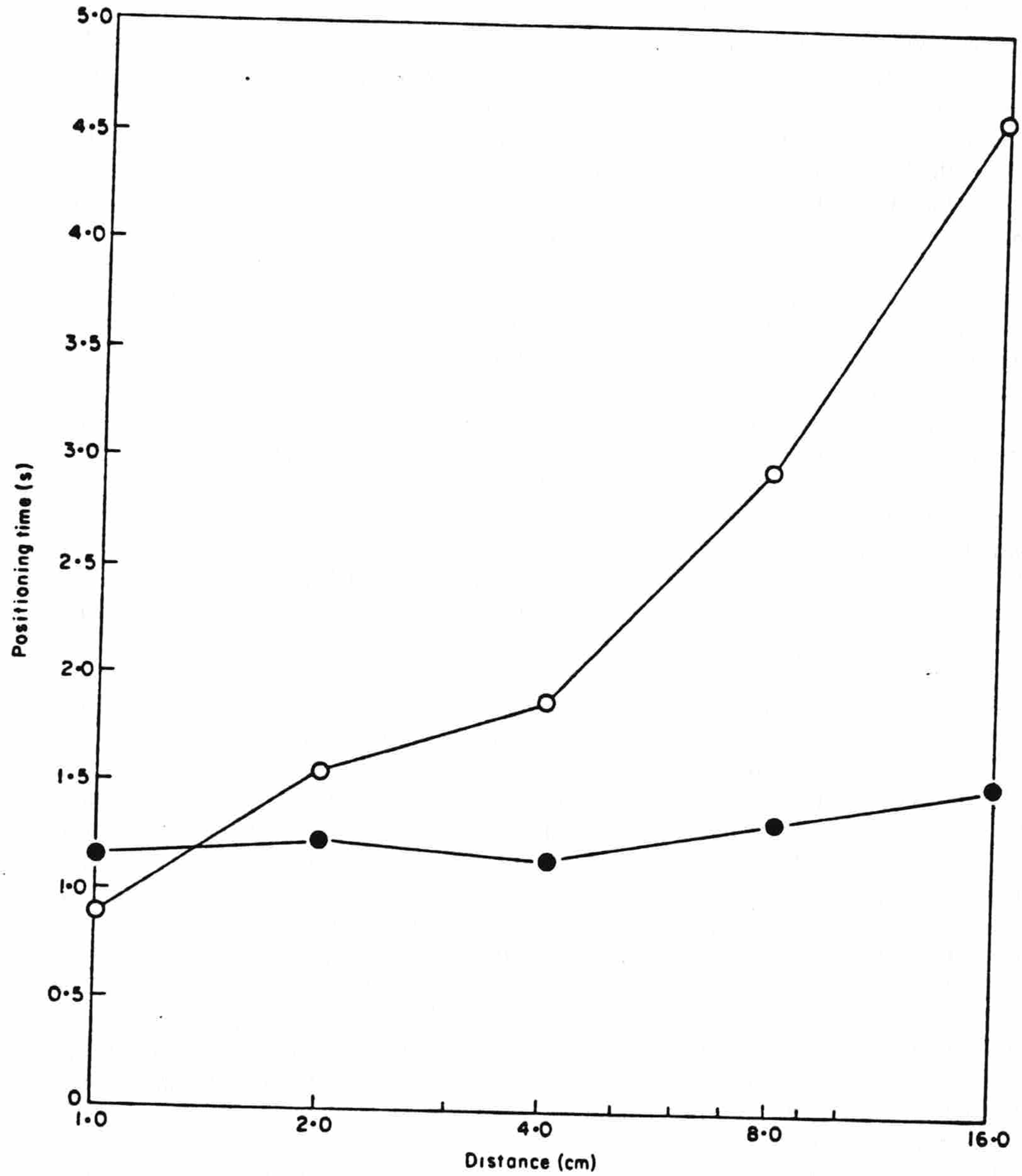

FIG. 3. Effect of target distance on positioning time for arrow keys and mouse, from the study of Card *et al.* (1978). ○—○, arrow; ●—●, mouse.

(1968) which relates positioning time (T) to distance to the target (D), size of target (S) and two empirically derived constants (K_0, K) as follows:

$$T_p = K_0 + K \, . \log_2 (D/S + 0.5) \, . \, S. \tag{1}$$

The two constants were derived from the mouse data to produce an equation which explained 83% of the variance in mouse positioning time means for various distance/target size conditions. Card *et al.* claim that the constants in the equation are close to the optimal values obtained for finger pointing. A similar equation, fitted to the arrow data, explained 95% of the variance.

The previous study's results show that the mouse was clearly the superior device of the four tested since with it were associated the quickest positioning time, the lowest error rate, and the Fitt's Law fit indicated that the rate of movement of the mouse is nearly maximal with respect to the information processing capacities of the eye-hand guidance system. A study by Karat, McDonald and Anderson (1984) however, has rather different conclusions regarding the mouse. Their study compares user satisfaction and path completion times associated with a mouse, a touch screen, and a keyboard. The keyboard method in their experiment did not involve the use of arrow keys, but rather involved simply typing a letter associated with the current target. Thus, that study does not provide a direct comparison of mouse and arrows like the previous one does, but is still relevant to our experiment due to its methods and its study of user satisfaction. Their study, like ours, used devices with an IBM PC in menu task environments. Targets consisted of outlined boxes with a single letter inside. Target selection time was measured from the appearance of the target on the screen until the selection of the target with the selection device. Another measurement was made of the time required to complete a menu traversal.

Results were obtained for 24 participants who were mainly female and whose ages varied from 18–57·83% of the participants had word-processing experience. Subjects completed 25 practice trials with each device and then performed 20 subsequent tasks (comprising a menu traversal) with each device. Results on user satisfaction report that the mouse was the least preferred device among the three tested. Also, the mouse was found to have the longest times for the practice tasks and for the menu traversal. Since the subjects were all skilled typists, and the mouse was a new device for all of them, the experimenters stated that they were not surprised to find advantages for typed and hand-pointing mechanisms. They claim that a major factor influencing the advantages of a device is the "naturalness" of the device. An ideal device should not require instruction in its use, and, when used, should be associated with minimal human cognitive costs and motor components. Karat *et al.* conclude by saying that more attention needs to be given to the nature of the dialogue for which the device is being used and to the skills of the users.

A study which measured the effect of computer experience on performance with arrow keys and a joystick is reported by Sweetak & Miller (1982). Participants in their experiment were asked to use a device to perform three tasks which were timed. Their results showed that people without computer experience were able to complete the tasks fastest with the joystick and that people with computer experience were able to perform equally well with either device.

1.5. DIFFERENT PERSONALITY TYPES INVESTIGATED IN THIS STUDY

Another aspect of this study is to investigate the relation of personality type and performance for different selection methods. Jungian theory of personality type has provided a consistent way of looking at individual differences. The theory differentiates between individuals based on perceptual and judgmental differences as major components. Each person is said to demonstrate preference in a set of pairs, these being extroversion vs introversion, sensation vs intuition, thinking vs feeling, and judgment vs perception. In our experiment, we have used the Myers-Briggs type indicator to determine where subjects fall within the various personality dimensions.

The perceptual aspect of personality is the way people perceive things. The judgmental aspect is the way people judge the things that have been perceived. The two ways of perceiving are sensing and intuition. Sensing is a way in which we perceive things as sensed by our five senses and intuition is an indirect form of perception in which what is perceived through the senses is combined with ideas and unconscious thoughts within a person. The two ways of judging things are feeling and thinking. Feeling-type people arrive at conditions and judgments about things through subjective evaluations. The thinking-type people base their judgments on logic and facts.

The other two traits that the Myers–Briggs Type Indicator looks at are extroversion vs introversion and judgment vs perception. These are more general in nature. The introverted type bases his or her perception and judgment on the inner self while the extrovert perceives and judges on the basis of the external environment. The judgment and perception preference is the way of looking at the outside world. The judging type quickly judges the environment, not always waiting for all the facts to come in, while the perceptive type waits until the last minute to make a decision or pass judgment, waiting for more pertinent information to surface. The main interest in this study is on the extroversion/introversion and sensing/intuition aspects of personality and how it relates to preference and performance with the selection methods. The following statements discuss in more detail those personality types which are studied in our experiment. Most of this information is obtained via Myers (1983), Bradway (1964), and Keirsey and Bates (1984).

Extroversion vs introversion

Introverts perceive and judge things in relation to their inner ideas and familiar concepts. They base their perception and judgment on previously formed inner conclusions. It is extremely important for introverts to have the right idea. To achieve this they often pause before taking action. They are less dependent on external stimuli at a particular moment, making their perceptions and judgments more constant. Myers (1983) reports that 25% of people fall into this type category.

Extroverts are mainly concerned with external stimuli and base their perception and judgment on those stimuli received at a given moment. They are not likely to be as consistent as introverts. Seventy five per cent of the population usually fall in this category.

Sensing vs intuition

Familiar concepts and tasks are appealing to sensing types, who are usually considered practical. Seventy-five per cent of the general population is claimed to fall within this category.

Intuitive types are imaginative and act on intuition. They enjoy symbolic and theoretical concepts and relations. They prefer doing new things as opposed to following the same routine. They are not very interested in details.

These two type categories when combined, form four categories in which the interaction of the categories differentiate one group from another. The four groups are:

Extroverted sensing (ES)

Extroverted sensing types rely more heavily on the objective element of their senses. They see things as a concrete reality and enjoy them as such. Their life is a consequence of outer happenings. They have a rich collection of experience which they have not fully comprehended.

Introverted sensing (*IS*)
Introverted sensing types rely more heavily on the subjective element of the stimuli received. They tend to concentrate on what pertains to their interest, therefore being selective to what they pay attention.

Extroverted intuitive (*EN*)
The extroverted intuitive people are constantly seeking new changes in objective situations. They find it very easy to express themselves and usually initiate and promote new ideas.

Introverted intuitive (*IN*)
The introverted intuitive people try to get an understanding of objective situations. They seek change, but changes that involve a subjective element also. They are considered to be creative, and their greatest value is in the interpretation of life.

An experiment designed in part to study the effect of perceptual personality type on comfort and success with computerized counseling has been described by Erikson, Fabizak & Pettruci (1983). They collected 41 subjects from the University of Maryland Psychology Department subject pool and divided them into four groups of introverted/extroverted and sensing/intuitive types. The types were discriminated on the basis of performance on the Kerisey Temperament Sorter, which is a condensed version of the Myers–Briggs Type Indicator. Out of the 41 participants in their experiment, only two were introverted/sensing types and only six were introverted/intuitive types. The subjects were divided into two groups: one group used a computerized career-counseling system, and the other group listened to a traditional lectured presentation. Prior to the career-counseling activity, subjects were given a questionnaire which was designed to measure comfort/anxiety. A post-questionnaire assessed comfort levels once more, plus how successful the activity was, i.e. whether the participants felt they benefited from the experience. For the people who used the computer, comfort and success levels were not found to be significantly different between the various personality types.

1.6. EXPERIMENTAL HYPOTHESIS

There are a large number of variables which we intended to study to see whether or not they affect device preference and performance. The effects of computer experience and typing ability was investigated, since people with certain backgrounds may be very familiar with, and thus perhaps do better with, the arrow-jump method. People with previous mouse experience may prefer the mouse and also perform faster with it. There may also be some dependence on video game experience, since some video games (e.g. Missile Command) are in large part an exercise in cursor positioning, albeit via different cursor-control mechanisms. Average target distance along equally long paths is also an independent variable to be studied. Card *et al.*'s results lead us to believe that the arrow-jump method may be quickest for short target distances while the mouse should be quickest for long distances. The effect of device order will also be studied.

Despite the lack of a dependence on personality type of the results of the Erikson *et al.* experiment, we still have reason to believe a dependence on type may exist on device preference and performance. The EN types are expected to prefer the mouse since it is a new device, therefore being more challenging and a change from the routine keyboard. The IS types would probably prefer the keyboard since it is more in conjunction with their needs of familiarity. The ES and IN types may be divided in their preference of the devices in question. The sensing types may take longer to perform their tasks than the intuitive types since they want to make sure of what they are doing.

2. Experimental methods

2.1. SUBJECTS USED IN THE EXPERIMENT

All the subjects used in the experiment were obtained from the University of Maryland Psychology Dept subject pool. All were taking a psychology course and participation in various experiments was a requirement for their course. Thirty-five subjects participated in our experiment. Two of the subjects were disqualified since one had to leave during the experiment due to a lack of time (approximately 30–40 min were required of each participant's time) and another one had filled out the subjective questionnaire incorrectly. In all subsequent references to the subjects, we will be referring to the 33 who were not disqualified.

The subjects ranged in age from 17–24. Table 1 shows various attributes of the group of subjects. Most were female (70%) and there was an even distribution of people who did and did not have computer experience, did and did not play video games, and who were either fast or slow typists. Only one subject (3% of the group) had previous experience with a mouse.

Table 1 also shows the percentage of various personality types as deduced from the Myers–Briggs test results. Two-thirds of the subjects were extroverts; there was an even split between sensing and intuitive types; there were twice as many feeling types as thinking types; and, finally, there were very many judging types as opposed to very few perceptive types.

TABLE 1
Various attributes of the group of subjects

Sex		69·7% Female	30·3% Male
Computer experience		45·4% None	54·5% Some
Mouse experience		97·0% None	3·0% Some
Video game experience		48·5% None	51·5% Some
Typing speed		48·5% Slow	51·5% Fast
E/I	66·7% E	15·2% X	18·2% I
S/N	39·4% S	12·1% X	48·5% N
T/F	24·2% T	18·2% X	57·6% F
J/P	81·8% J	9·1% X	9·1% P

Personality types: E, extroverted; I, introverted; S, sensing; N, intuitive; T, thinking; F, feeling; J, judging; P, perceptive; X, equal.

2.2. MATERIALS USED IN THE EXPERIMENT

The Myers–Briggs type determination was performed through the Keirsey Temperament Sorter (KTS) in the form of a 70-item questionnaire. The questionnaire surveyed preferences and behavior patterns. Responses to the questions are added up in such a way so as to estimate where each person lies within the four personality dimensions.

A practice path was designed so subjects could practice with each device a short time before a timing test was conducted for that device. The practice path was a sequence of eight targets listed on a sheet of paper which was given to the subjects at the start of the practice session. The mouse practice path listing differs from the arrow-jump practice path listing only in that where the latter may have "PRESS RETURN TO CONTINUE", the former would have "PRESS THE MOUSE BUTTON TO CONTINUE". The words on the path listing were double spaced so subjects could easily keep track of where they are on the path.

Also, there were two paths designed for the timing tests. A mouse path listing differed from a corresponding arrow-jump path listing again by the phrases "RETURN" and "THE MOUSE BUTTON". Each path consisted of 28 words. One path, called the "Short Target Distance (STD) Path", consisted of targets which, on the average, were less than two targets away from the initial cursor position for the various screens encountered. That is to say, that "shortness" of target distance is defined here relative to the arrow-jump method: the movement of the cursor to a typical target in the STD path requires less than two depressions of an arrow key. The physical distance to the target in the STD path (which is relevant to the mouse usage) is variable, but tends to be smaller there than in the long target distance (LTD) path. In Fig. 1, "NEXT PAGE", "REICH SECURITY MAIN OFFICE", or "END" may be typical targets in the short path.

The long target distance (LTD) paths were characterized by targets which were, on the average, more than two targets away from the initial cursor position. Subjects were presented with one of the path listings for the timing tests.

A subjective questionnaire was presented to the subjects upon completion of all timing tests. The questionnaire was on two sheets of paper and consisted of five multiple choice questions and two comment requests.

2.3. PROCEDURE

A subject's first task was to read and sign the experimental consent form. After that, he/she would complete the KTS questionnaire. Then the computer would ask various questions, to which responses would be given via the keyboard. The questions asked regard the subject's age, sex, whether or not he has computer experience (Yes/No), whether or not he has used a mouse before (Yes/No), whether he plays video games (Yes/No), and what speed a typist he is (Fast/Slow). Then the subject was given an overview of TIES, and an introduction to the mouse and arrow-jump devices. After this, the subjects were given a practice path listing to traverse with one of the devices. Half of the subjects started with the mouse method and half started with the arrow-jump method. Upon completion of the practice path, the subject begins either the STD or the LTD path, having received a listing of the path just prior to the end of the practice session. Subjects were told to place their finger on the list so as to keep track of where they are, and put the list wherever it was comfortable. Half of the people using either device used the STD path and the other half used the LTD path. The computer recorded the time required for the path completion, with the timing starting at the end of the practice session and ending with the selection of the last target on the path. If, while traversing a timed path, a subject makes an error (i.e. selects a wrong target), then our procedure would be to have him restart the path with the timing being reset. A tally was kept of the number of errors made by each subject for each device.

The subject then began the practice path with the other device, again receiving a short explanation as to how to use it. The subject then performed another timed path traversal with the same path (STD or LTD) used for the previous device. This allows a direct comparison of each individual's timing scores for the two devices with everything constant except order.

The subject then completed the subjective evaluation questionnaire.

3. Results

3.1. EFFECTS OF ALL INDEPENDENT VARIABLES OTHER THAN PERSONALITY ON COMPLETION TIME AND DEVICE PREFERENCE

For combined path completion times, regardless of target distance, the device effect was found to be statistically significant at the 5% level. For the STD path, the device effect was found to be significant at the 1% level in explaining the STD path completion times. For confined path completion times, regardless of target distance, the device effect was found to be statistically significant at the 5% level. For the STD path, the device effect was found to be significant at the 1% level in explaining the STD path completion times. For the LTD path, the device effect was not significant at the 5% level. Traversals of the STD path were faster on the average with the arrow-jump method (170·1 s) than with the mouse (200·0 s). Likewise, traversals of the LTD path were on the average faster with the arrow-jump method (198·0 s) than with the mouse (209·3 s). These results are illustrated in Fig. 4, which may in some sense be compared with the results of Card *et al.* shown in Fig. 3. Even though the TIES arrow keys behave differently than theirs, and the targets and the measures of target distance were different, there are similarities. Both figures show that the mouse times are less dependent on target distance than are the arrow times. The main difference is that for our situation, on the average, the arrow-jump method was always faster than the mouse.

A problem associated with the arrow-jump method though is that, throughout the experiment, nine errors were made using it, whereas only two errors were made with the mouse.

Table 2 shows the mean values of path completion time with the arrow-jump method and with the mouse, plus the average preference for the arrow-jump method (in per cent) for various groups of specific values of independent variables. The results regarding device order show that subjects tended to perform faster with the arrow-jump method, regardless of which device they started with. It is also seen that subjects who used the mouse last had a higher perference for it than did those subjects who used it first.

The effects of target distance on path completion times were already discussed in part at the start of this section. Table 2 shows us something else regarding target distance in that subjects who used the STD path had a higher preference for the mouse than did those subjects who used the LTD path, perhaps because the mouse had to be repositioned whenever it came to the end of the table, which would happen more frequently in traversing the LTD path.

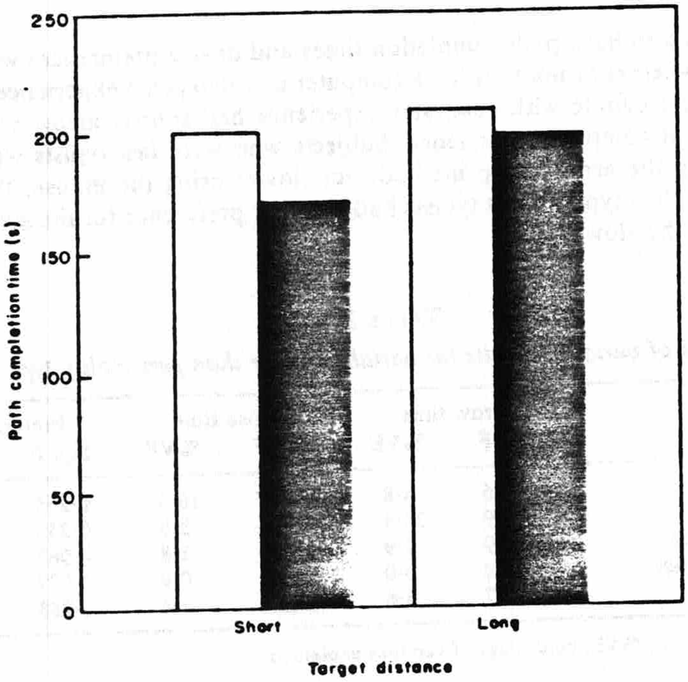

FIG. 4. Path completion time for arrow-jump and mouse methods as a function of average target distance of the traversed path. ■, arrow; □, mouse.

TABLE 2

Average values of arrow-jump and mouse times plus mouse preference for various values of independent variables

		Number	Arrow time (s)	Mouse time (s)	Arrow preference (%)
First Device	Arrow	16	191·1	197·0	81%
	Mouse	17	178·3	211·9	94%
Target distance	Short	16	170·1	200·0	81%
	long	17	198·0	209·3	94%
Computer experience	None	15	196·1	207·3	87%
	Some	18	174·8	202·6	89%
Video game experience	None	16	184·6	206·8	87%
	Some	17	184·5	202·7	88%
Typing speed	Slow	16	194·3	201·7	81%
	Fast	17	175·3	207·6	94%

Subjects seemed to have path completion times and device preferences which were independent of whether or not they have computer or video game experience. The one exception was that people with computer experience had shorter arrow-jump times than those without computer experience. Subjects who were fast typists were found to be faster using the arrow-jump method, but slower using the mouse, than those people who were slow typists. Fast typists had a higher preference for the arrow-jump method than did the slow typists.

TABLE 3

Analysis of variance results for variables other than personality type

	Arrow time		Mouse time		Preference	
	Sig. F	%VE	Sig. F	%VE	Sig. F	%VE
First device	0·186	4·8	0·070	10·0	0·255	3·7
Target distance	0·009	20·4	0·253	3·9	0·255	3·7
Computer experience	0·109	7·9	0·450	1·8	0·967	0·0
Video game experience	0·979	0·0	0·582	0·9	0·977	0·0
Typing speed	0·177	5·6	0·381	2·4	0·283	3·8

Sig. F, significance of F; %VE, percentage of variance explained.

Table 3 shows the results of an analysis of variance performed on arrow-jump and mouse completion times and device preference for the same independent variables from Table 2. Two-way and higher interactions are not considered. Nothing is statistically significant at a standard level (1% or 5%) except for the effect of target distance on arrow-jump completion time, which is significant at the 1% level.

3.2. EFFECTS OF PERSONALITY TYPE ON PATH COMPLETION TIMES AND DEVICE PREFERENCE

Table 4 shows average arrow-jump and mouse times plus mouse preference for ES, IS, EN, and IN groups, Table 5 the results of an analysis of variance regarding personality types. The numbers of subjects falling into the four personality categories in Table 4 are not sufficient to give a strong basis for the results of this section (there are only 2 ISs). A large number of the subjects did not fall into one of these groups since they were centrally placed on the E/I and/or S/N spectrums. The various

TABLE 4

Effect of personality type on device completion time and user preference

type	Number	Arrow time (s)	Mouse time (s)	Arrow preference (%)
ES	7	191·4	213·2	100%
IS	2	172·4	203·4	100%
EN	11	168·5	204·1	91%
IN	4	186·9	211·4	100%

TABLE 5

Analysis of variance regarding personality types

	Arrow time		Mouse time		Preference	
	Sig. F	% VE	Sig. F	% VE	Sig. F	% VE
E/I	0·132	11%	0·642	3%	0·559	3%
S/N	0·231	8%	0·441	6%	0·058	19%
Two-way E/I, S/N	0·188	9%	0·702	2%	0·681	2%
T/F	0·787	2%	0·107	12%	0·927	1%
J/P	0·917	1%	0·344	5%	0·688	3%

Sig. F, Significance of F; % VE, percentage of variance explained.

groups do not have much variability with respect to device usage time, but it is interesting to note that the EN group is the only group of the four which did not unanimously prefer the arrow-jump method. We mentioned as part of our hypothesis (in section 1), that the EN types may have a stronger basis for preferring the mouse than do the other groups.

Table 5 shows analysis of variance results. Results for thinking/feeling and judging/perception levels are included since the data are available. One can see that there is nothing in the table which is significant at the 5% level. The effect of sensing/intuitiveness is almost significant at that level though in relation to the device preference values. Though our data may not be large enough for a more sound analysis, these results support the belief that personality type does not have much of an influence on the dependent variables studied here.

3.3. SUBJECTIVE QUESTIONNAIRE RESULTS

The overall device preference, discussed in Section 3.1., has been found to be for the arrow-jump method at 88%. The subjective questionnaire was designed to clarify reasons why a device should be preferred, as well as shortcomings. The following discussion details the implications of the averages of the numerical answers for the subjective questions.

The first question asked the subjects how comfortable they felt in using the devices on a scale from 1–5 (all five questions have this same scale) where 5 is the most favorable rating. The arrow-jump method, with an average of 4·5, did better than the mouse on this issue, which had an average response of 3·3.

The second question surveyed how much control the subjects had over the devices, with the concept of control left up to the subjects' interpretation. The arrow-jump method again outscored the mouse: 4·5 to 3·3.

Enjoyment in using the devices was the topic of the next question. The arrow-jump method was reported as being more enjoyable, with an average score of 4·2, as compared with the mouse, whose score was 3·6.

The fourth question asked the subjects how frequently they had to look at the selection device when moving the cursor, again on a scale of 1–5. 1 here meant always and 5 meant never. Here the average arrow-jump score was 3·3 and the corresponding mouse score was 4·0, indicating that the arrow-jump method is more visually demanding.

The last question asked how easy it was to position the cursor. The arrow-jump method did better here, the averages being 4·6 (arrow-jump) vs 3·0 (mouse).

4. Discussion

4.1. ORAL REMARKS MADE BY THE PARTICIPANTS REGARDING THE DEVICES

A very important part of this experiment was finding out the subjects' satisfaction and dissatisfaction with the mouse vs the arrow-jump method. Subjects mentioned that the mouse can move the cursor "directly to any word whereas the arrow-jump method sometimes requires multiple keystrokes to locate a word". When using the arrow-jump method, the cursor must pass through intermediate highlighted words to get to a particular word which, in fact, resulted in occasional cursor movements being misguided from the direction the cursor was intended to be move. Some subjects said that the mouse provides a "more natural way" in moving the cursor in the intended direction (Karat *et al.*'s paper stresses such feelings of naturalness). One subject said that "the mouse may be easier for non-typists". One more comment about the mouse was that it was "fun to use", and that "given more experience with it, I would come to like it".

The common consensus among the subjects, however, was that the arrow-jump keys "provided more control", were "easier to use", and "were more familiar". They also said that they prefer a stationary device". Some subjects said they preferred the arrow-jump method since it required "less arm movement". They said they felt more comfortable if their hand was in one place when controlling a device. Almost all the subjects had previous experience using some type of keyboard which is probably a contributing factor to why the arrow-jump method was more comfortable.

Some subjects had difficulty positioning the cursor on a highlighted word using the mouse, and subjects said it "required some concentration and eye-hand coordination". A few subjects expressed frustration with the mouse and even attempted to rotate the ball underneath the mouse (like a trackball) when rolling the mouse on the table didn't work for them. One more advantage mentioned about the arrow keys was that they were "less prone to damage", whereas a mouse could fall off the table or be separated from its wire.

4.2. EXPERIMENTERS' COMMENTS

This study was geared toward studying user performance and satisfaction in selecting text in a short-term situation. This approach was taken since TIES may be installed in a museum, in which it would seem likely that most encounters with the system would be brief. The superiority of the arrow-jump method, supported by our results, may possibly vanish in a long-term environment since Card *et al.*'s study of long term use showed the mouse to be superior. Our sole participant who had mouse experience ended up preferring the mouse overall. If we had more participants with previous mouse experience, we would have liked to study the effect of that variable.

Another dependent variable regarding the appropriateness of the adoption of a given device for TIES, other than speed and preference, is whether distraction caused by using the device affects the user's comprehension of the material on the screen. This variable was not directly investigated (e.g. via a reading task and a comprehension test) since our experimental results are already rather large for the variables studied.

Part of our results for the subjective questionnaire responses are relevant to this topic though: people claimed that they had to look down at the arrow and return keys more frequently than they had to look at the mouse, which supports the notion that the arrow-jump method may be more disruptive. Also, the fact that more errors (path deviations) were made with the arrow-jump method than with the mouse supports the same notion.

Various experiments in the future will examine the use of touch screens as another possible selection device to be used in conjunction with TIES.

5. Conclusions

This experiment studied the effects of numerous independent variables on time for path completion using mouse and arrow-jump methods, and on device preference. The effect of device was found to be significant at the 5% level in relation to the path completion times. The arrow-jump method was found to be quicker, on the average, than the mouse method for the two paths studied. Both paths had an equivalent length (number of targets) and were characterized by either short or long target distances. Path traversal times were found to be more dependent on target distance for the arrow-jump method than for the mouse method. The arrow-jump method was also associated with more errors than was the mouse method. Both of the previously mentioned results are consistent with the results of Card *et al.* Also, as in the results of Karat *et al.*, the mouse was found to have the lowest subjective preference of the devices studied.

Computer experience and video game experience were found to have essentially no effect on the dependent variables. The effect of previous mouse experience was not determined due to a lack of data on that effect. Fast typists were found to have faster arrow-jump performance, slower mouse performance and a higher preference for the arrow-jump method than slow typists.

No aspects of personality type were found to be significant at the 5% level with regards to any of the dependent variables. The small number of subjects in some of the personality categories has a negative effect on the meaningfulness of the personality results.

Results from the subjective questionnaire indicated that the subjects felt that the arrow-jump method was more comfortable to use, more controllable, more enjoyable, and easier to use than the mouse method. It was also found that people felt that they had to look down more frequently using the arrow-jump method than when they used the mouse.

References

BRADWAY, K. (1964). Jung's psychological types. *Journal of Applied Psychology*, **9**, 129–135.

CARD, S. K., W. K. ENGLISH & B. J. BURR (1978). Evaluation of mouse, rate-controlled isometric joystick, step keys, and text keys for text selection on a CRT. *Ergonomics*, **21**, 601–613.

DE JONG, J. R. (1957). The effects of increasing skill on cycle time and its consequences for time standards. *Ergonomics*, **1**, 51–60.

ERIKSON, J., K. FABIZAK & D. PETTRUCI (1983). *Student Personality and Success with Brief Computerized and Lectured Career Counseling* pp. 1-46. Unpublished student project, University of Maryland, College Park, MD.

KARAT, J., J. E. MCDONALD & M. ANDERSON (1984). A comparison of selection techniques: touch panel, mouse, and keyboard. *Interact '84*, vol. 2, 4-7 September, 1984, London, England, pp. 149-153.

KEIRSEY, D. & M. BATES (1984). *Please Understand Me.* Gnosology Books, Prometheus Nemesis.

MERKIN, M. (1983). In love with Lisa. *Creative Computing*, **9**, 12-20.

MYERS, I. B. (1983). *Gifts Differing.* California: Consulting Psychologists Press.

SWEETAK, D. & J. B. MILLER (1982). *Graphical Input Methods Analysis*, pp. 1-18. Unpublished student project, University of Maryland, College Park, MD.

WILLIAMS, G. (1983). The Lisa computer system. *BYTE*, **8**, 33-50.